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M.R.P. 823 REVISED

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AIR MINISTRY
METEOROLOGICAL RESEARCH COMMITTEE

The average vector wind distribution of the upper air in temperate and tropical latitudes

by
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Summary

Charts have been drawn showing, for the months of January, April, July and October, and for the area between the latitudes of 60°N. and 50°S., the isotachs of wind speed and the streamlines of wind flow at the levels of 500, 300, 200 and 100 mb.

Data

Preliminary charts have been prepared in the Upper Air Branch of the Meteorological Office of upper air temperatures over the world at the levels of 700, 500, 300, 200, 150 and 100 mb. for the months of January, April, July and October, with isotherms drawn at intervals of 2°C.

These were then amended slightly in some areas (India, Australia and South Africa) to include the latest available data.[1]

Theory

If $\theta(p_1p_2)$ is the thermal vector wind between two pressures p_1 and p_2, and n is a unit vector directed vertically, then

$$\lambda\,\theta(p_1p_2) = n \times \text{grad}\, h(1,2) \qquad (1)$$

where $\lambda = 2\Omega \sin\phi$

$$h(1,2) = \int_{p_1}^{p_2} (RT/g)\, d(\log p)$$

Ω is the earth's angular velocity

R is the gas constant

g is the acceleration due to gravity

T is the absolute temperature

$$h(1,2) = (R/g)\, T(1,2) \log_e (p_1/p_2) \qquad (2)$$

where $T(1,2)$ is the mean value of T on a T, log p diagram between the pressures p_1 and p_2

$$\theta(p_1p_2) = k(1,2) \left[n \times \text{grad}\, T(1,2) \right] \qquad (3)$$

where $k(1,2) = (R/\lambda g) \log_e (p_1/p_2)$

If the average monthly temperature at various pressure levels p is plotted against p the curve is essentially two straight lines, with a discontinuity at the tropopause.

/The

The layers chosen for the computation of thermal vector winds were 1000 - 500, 500 - 300, 300 - 200, 200 - 150, 150 - 100 mb. Apart from the layer including the tropopause the average curve of T, log p differs most from a straight line in the layer 1000 - 500 mb.; but even in this layer the mean temperature T (1000,500) is very nearly T (707) the temperature at 707 mb. (log 707 = $\frac{1}{2}$ [log 1000 + log 500]). At neighbouring places the way in which the average temperature curve differs from a straight line is nearly identical, and the rate of change from place to place of the difference between T(1000,500) and T(707) is of a very much smaller order than the rate of change of T(707), which is very nearly the rate of change of T(700).

Hence, very approximately

$$\theta\,(1000,500) = k\,(1000,500)\,\left[n \times \text{grad } T(700)\right] \qquad (4)$$

That is, the thermal wind of the layer 1000 - 500 mb. is in the direction of the 700 mb. isotherms with magnitude proportional to the gradient of temperature between the isotherms.

For the other layers above 500 mb. not including the tropopause, the mean temperature between any two levels is very nearly half the sum of the temperatures at the two levels; and the gradient of the field of mean temperature is very approximately equal to half the vector sum of the gradients of the temperature fields of the two levels.

For the layer including the tropopause, the curve of T, log p is two straight lines. Curves for neighbouring places are similar and the rate of change from place to place of the difference between T(1,2) and $\frac{1}{2}$ [T(p_1) + T(p_2)] is very much less than the rate of change of $\frac{1}{2}$ [T(p_1) + T(p_2)] . Hence also for the layer including the tropopause the gradient of the field of mean temperature is very approximately equal to half the vector sum of the gradients of the temperature fields of the two levels.

Thus the thermal wind of the layer 500-300 mb. is equal to half the sum of two vectors which are respectively directed along the isotherms of the 500 and 300 mb. temperature fields and with magnitudes proportional to the gradients of temperature at those levels; and similarly for other layers.

In the notation of equation (4),

$$\theta\,(500, 300) = \tfrac{1}{2}\,k\,(500, 300)\ \left\{\left[n \times \text{grad } T\,(500)\right] + \left[n \times \text{grad } T\,(300)\right]\right\}$$

.....

$$\theta\,(150, 100) = \tfrac{1}{2}\,k\,(150,100)\ \left\{\left[n \times \text{grad } T\,(150)\right] + \left[n \times \text{grad } T\,(100)\right]\right\} \qquad (5)$$

Method

A fixed grid of 234 points was chosen, the intersection of longitudes 180°W. (20°) 180°E. and latitudes 20°N. (5°) 40°N., 50°N., 60°N. and latitudes 20°S. (5°) 40°S., 50°S.

For each of the months January, April, July and October, at each grid point for the levels of 700, 500, 300, 200, 150 and 100 mb. measurements were made of the vector quantities whose directions were along the isotherms and magnitudes equal to the gradients of the temperature field. From these, substituting the appropriate values of the constants k, the thermal winds were obtained for the layers 1000-500, 500-300, 300-200, 200-100 mb., with speeds measured to the nearest knot and directions to the nearest five degrees.

The "surface" geostrophic vector wind at each of the 234 grid points was measured from mean sea level pressure charts, with isobars drawn at 4 mb. intervals, prepared in the World Climatology Branch of the Meteorological Office. Over the oceans a check was obtained from the charts of average winds for five degree squares prepared in the Marine Branch of the Meteorological Office [23]; and for some doubtful points over the continents from available manuscript data in the Meteorological Office.

The vector winds at 500, 300, 200 and 100 mb. were obtained by successive vector addition of the "surface" and thermal vector winds.

The vectors were plotted on sixteen Mercator charts which are reproduced as Figs. 1 to 16*. Isotachs of wind speed in kt. (full lines) and stream lines (pecked lines with direction arrows) were drawn. Most of the stream lines were drawn as isopleths of approximate contour height in hundreds of geopotential ft. The contour heights have been entered for the benefit of possible users but it should be understood that they are not complete in themselves. Areas with resultant wind speed less than 10 kt. were hatched in the tropics.

To help in drawing the charts, wind data were worked up for a number of stations, chiefly for three year periods between 1949 and 1952; and with the help of these data and other available data it was considered that the charts could be drawn up even in the tropical regions with considerable accuracy. Lists are appended of data worked up, data recently published or made available, and also of older material examined.

Footnote

* A limited number of charts, approximately double the size of those in the report, are also available.

APPENDIX I

Wind data worked up for three-year period

Athens [2,3]; Hanover[4]; Cairo[7].

San Juan (all months) and Bismarck, Columbia, Greensboro, Little Rock, Oakland, San Antonio, Tatoosh, Caribou, Oklahoma, St. Cloud, Big Spring, Brownsville, Charleston, Miami, New Orleans for the month of July only.[5]

Canton I, Honolulu, Midway I, Albrook Field, Marshall I, Guam, Manila, Wake I, Rome[3].

Gibraltar, Benina, Malta, Nicosia, Nairobi, Habbaniya, Bahrein and Aden from manuscript data in the Meteorological Office.

Lagos (1952 only)

Japanese stations, chiefly Wakkanai, Tateno, Shionomisaki, (1950-1).[6]

APPENDIX II

Wind data recently published or made available

Larkhill, Lerwick[8]; Poona (July 1949-50)[9];
Auckland, Nandi[10]; Singapore[11]; Hong Kong[12].

Falkland I., Aldergrove as manuscript data available in the Meteorological Office.

Mean winds for Japanese stations for the months of January, April and July 1952[6].

APPENDIX III

Older material examined

Cirrus cloud observations, Napier Shaw [13].
Lindenberg[14]; Batavia[15]; Mauritius[16]; Apia[17];
Ghanzi[18].
Cuyaba, Curityba, Santiago, Meteor[19].
Pilot balloon data for India [20,21]

Vector winds computed from medium and cirrus cloud observations for the United States and the Caribbean [22].

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JANUARY – 500mb.

Streamlines and isotachs of the average vector wind distribution

M.R.P. 823

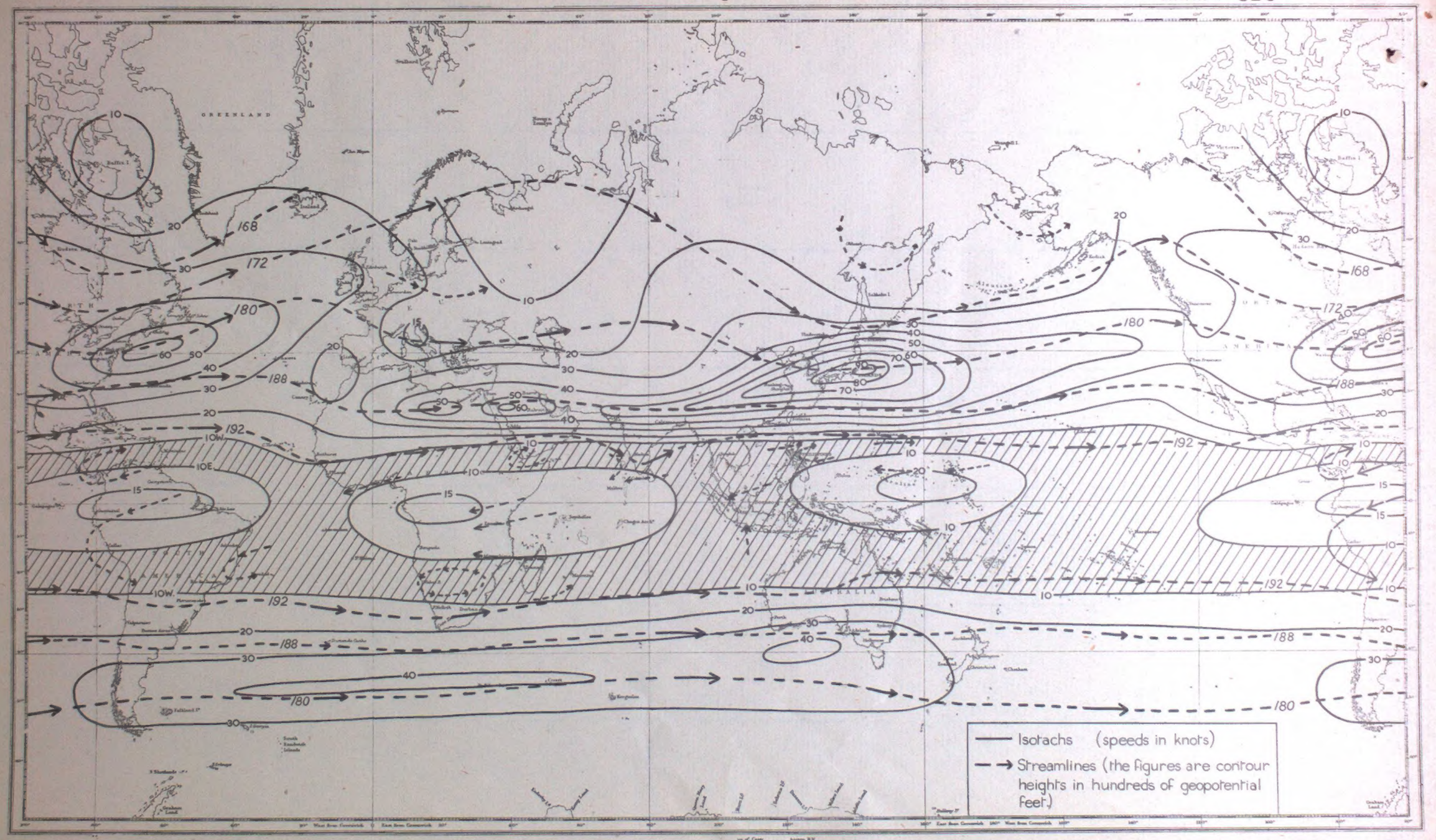

FIG. 1

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JANUARY – 300mb.

M.R.P. 823

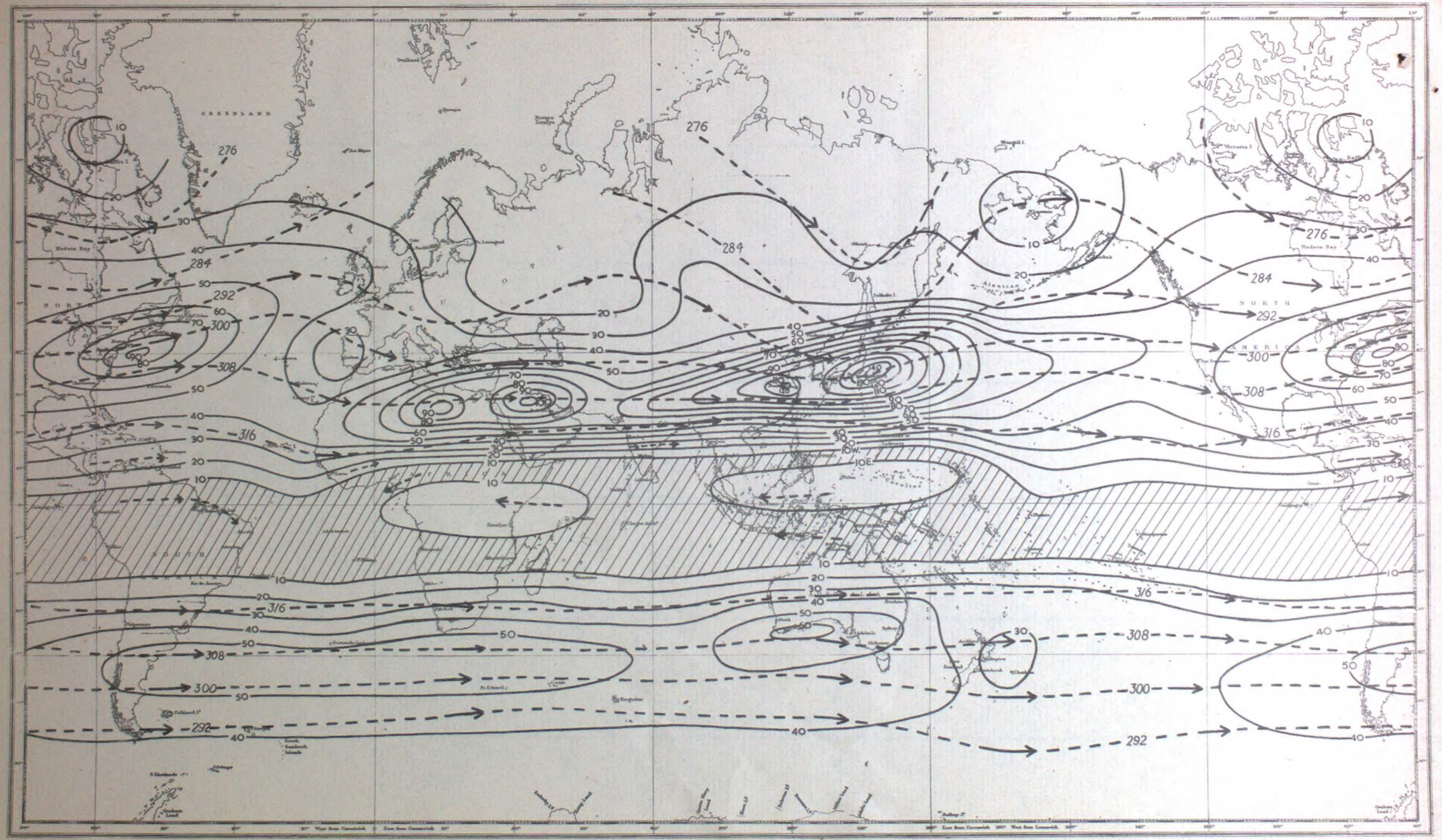

FIG. 2

JANUARY – 200 mb.

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M.R.P. 823

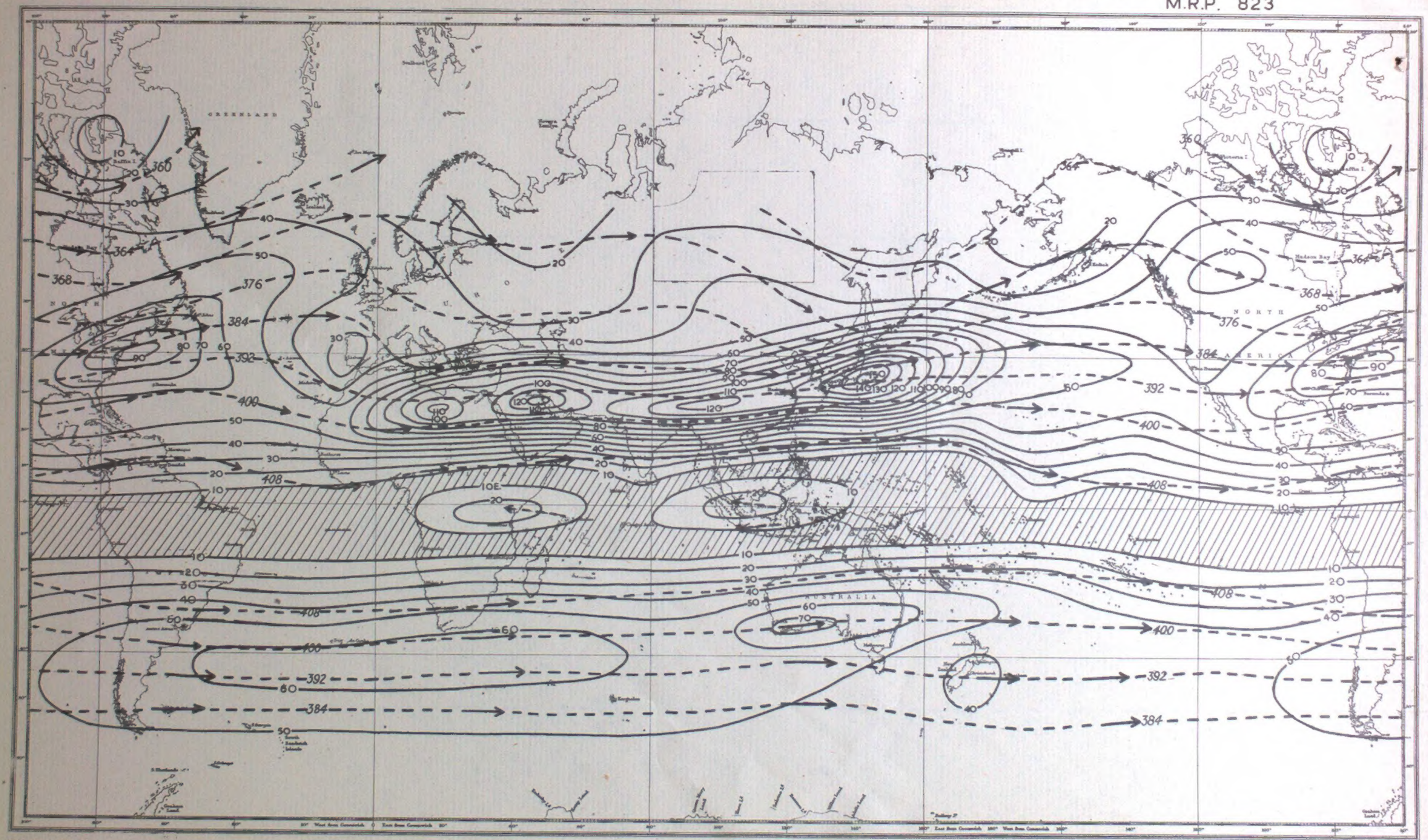

FIG. 3

JANUARY — 100 mb.

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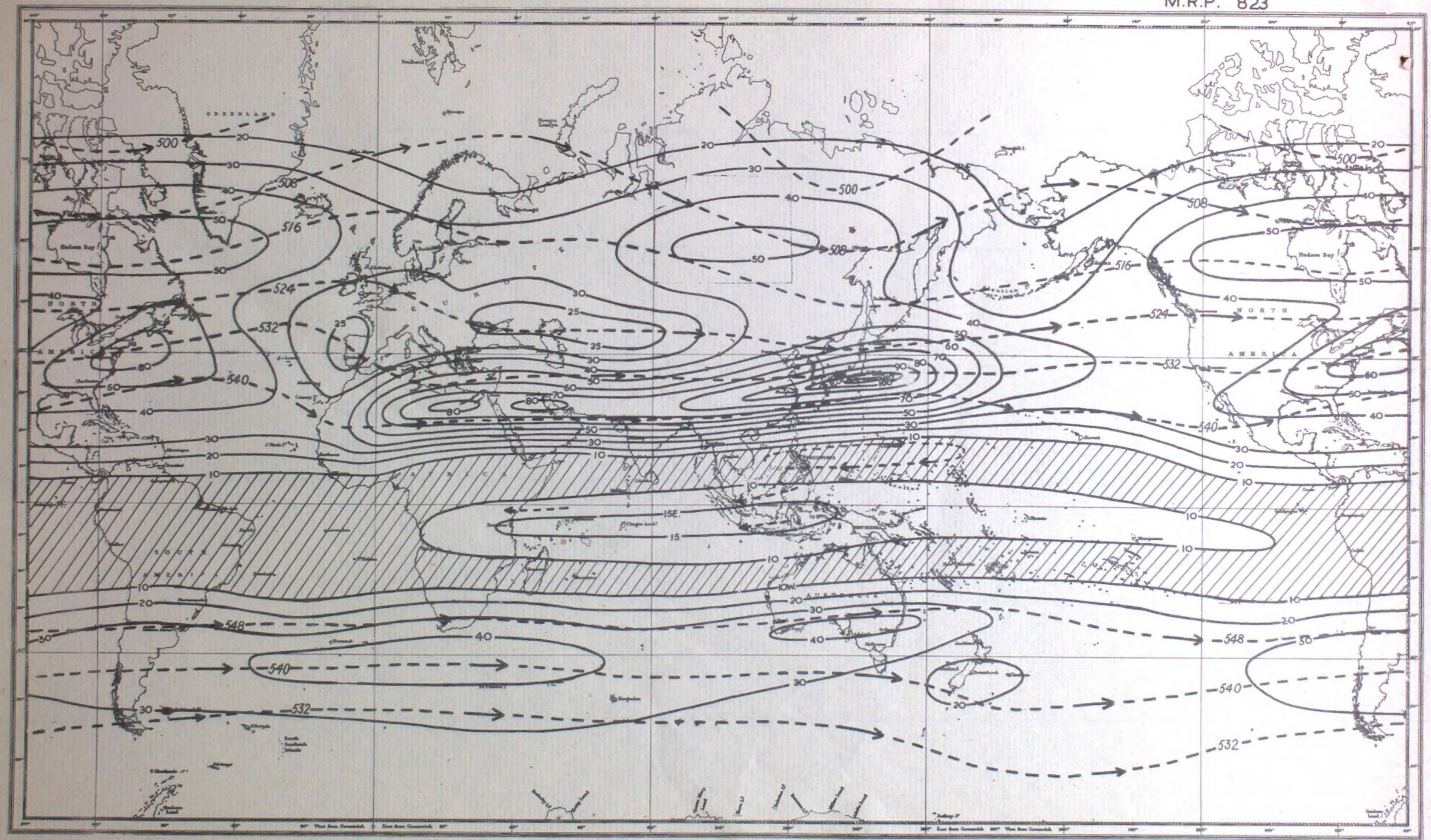

FIG. 4

APRIL – 500mb.

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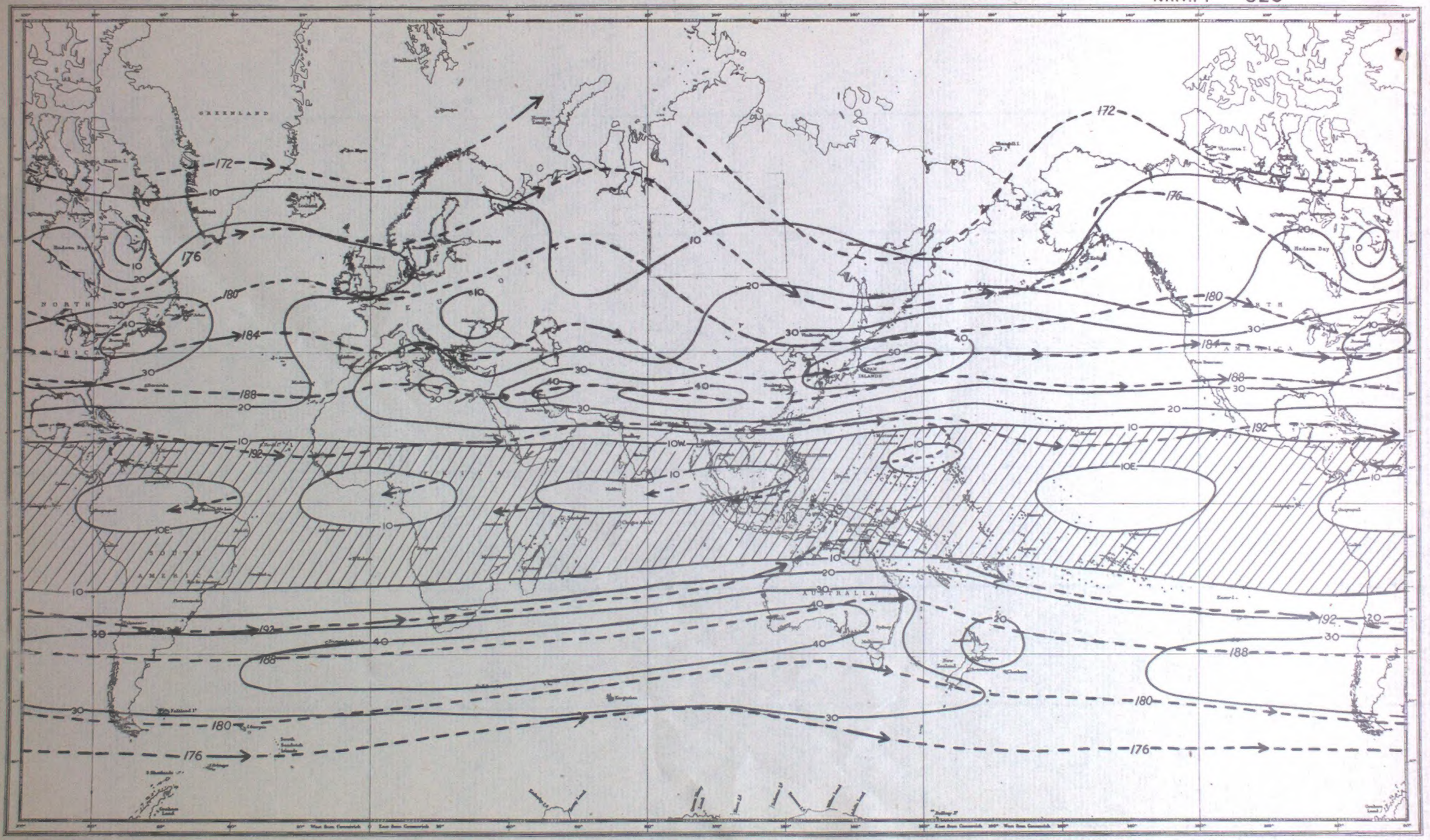

FIG. 5

APRIL – 300mb.

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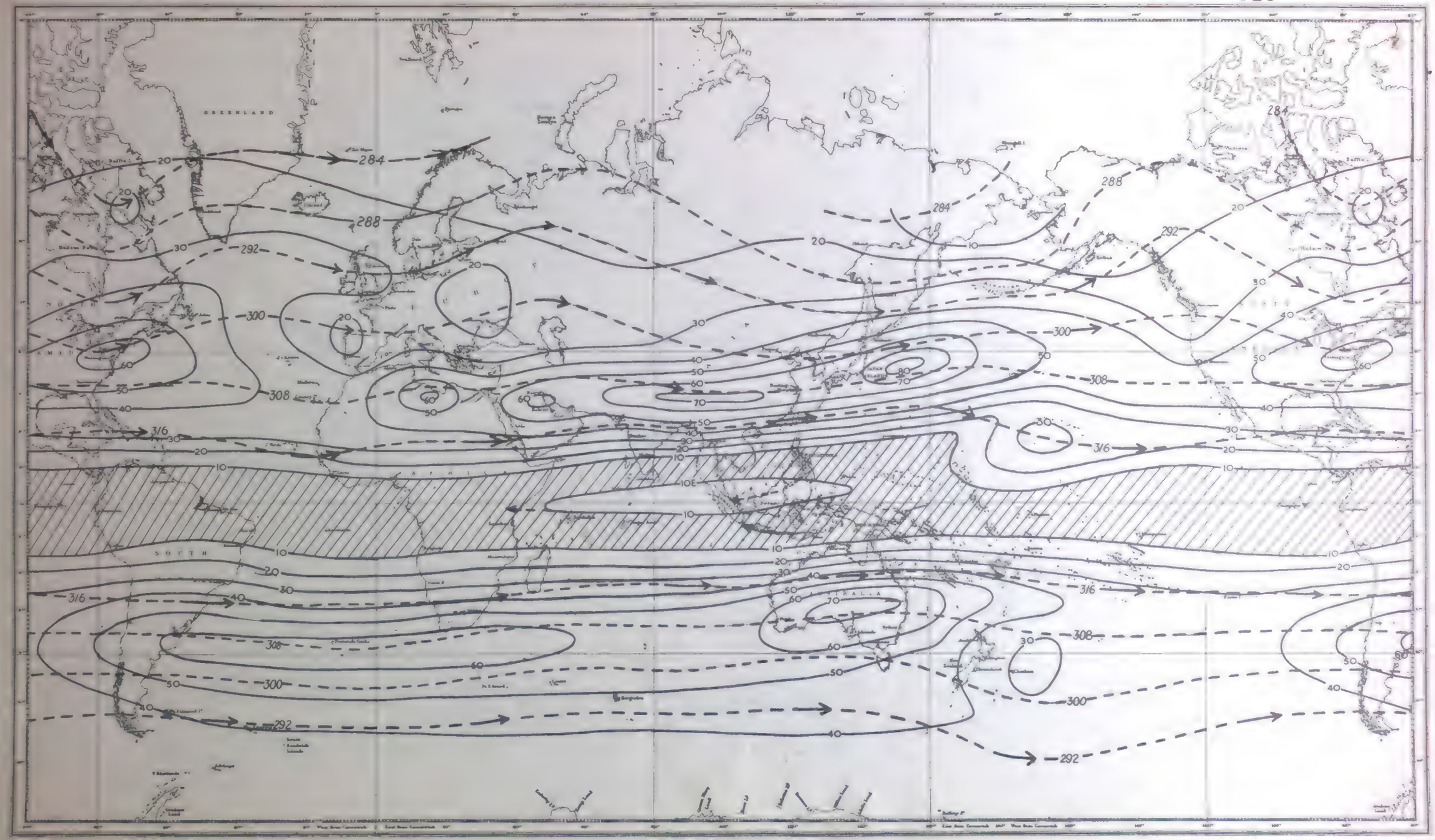

FIG. 6

APRIL - 200mb. PROVISIONAL M.R.P. 823

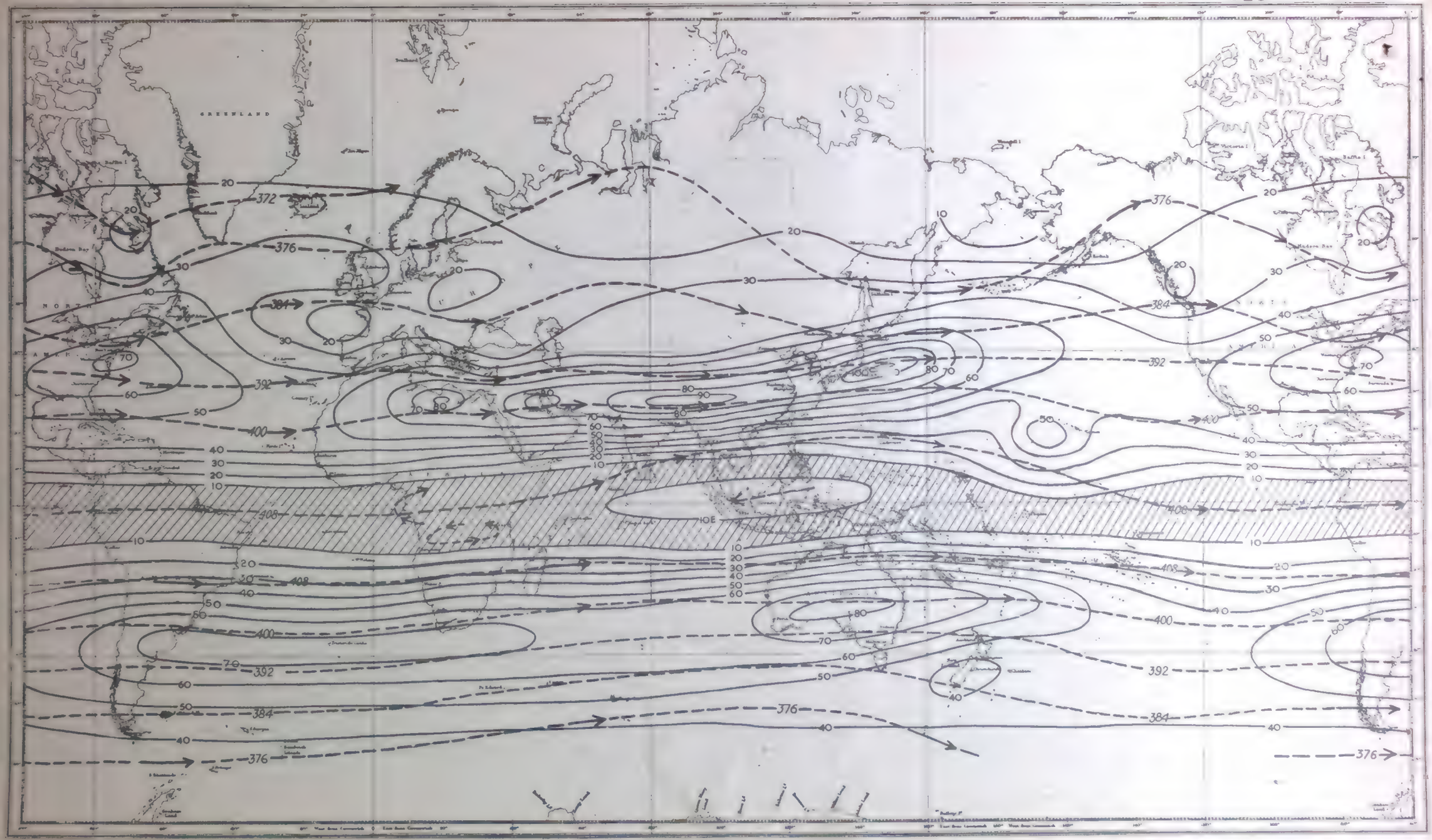

FIG. 7

APRIL – 100 mb.

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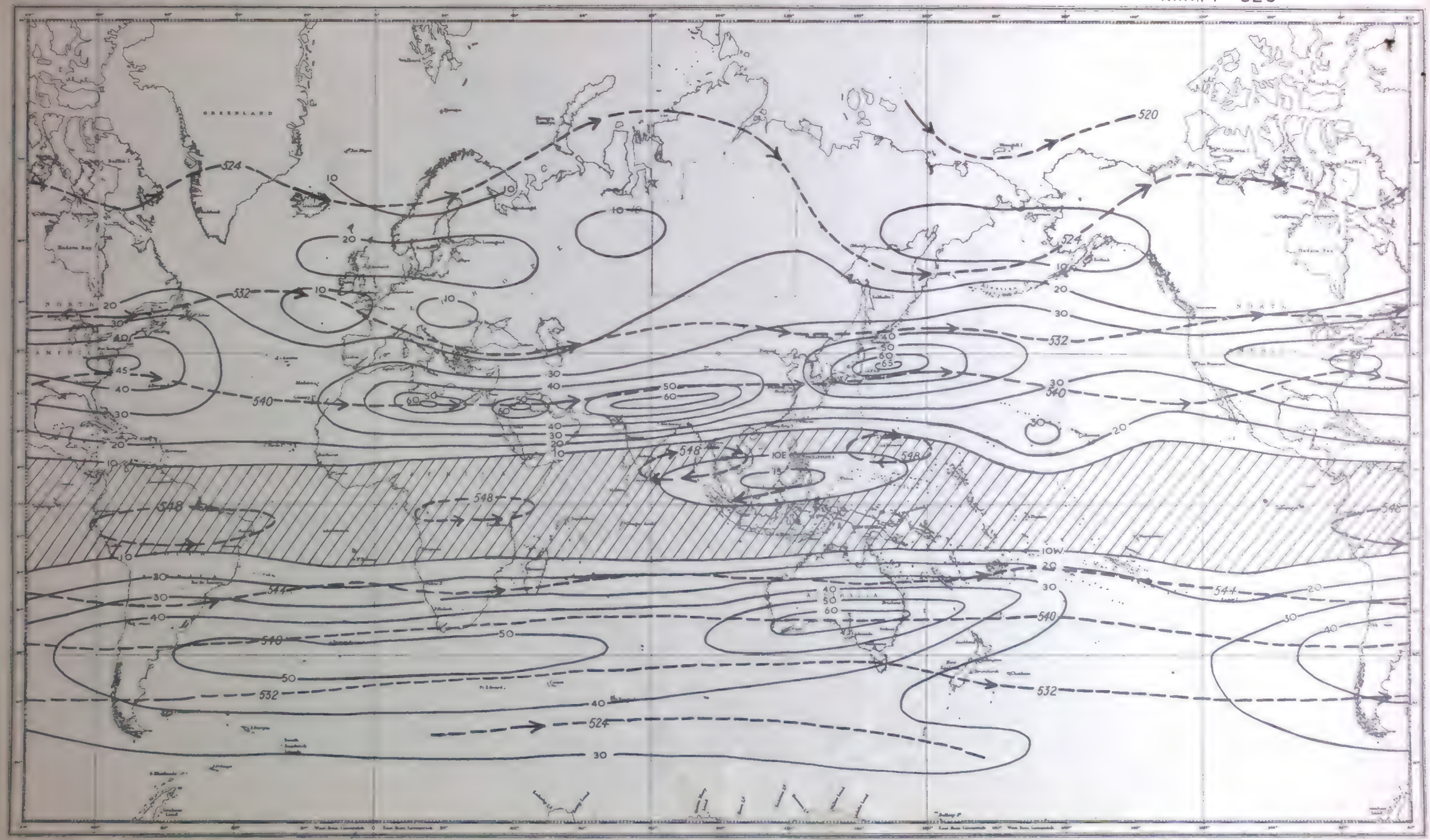

FIG. 8

JULY – 500 mb.

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M.R.P. 823

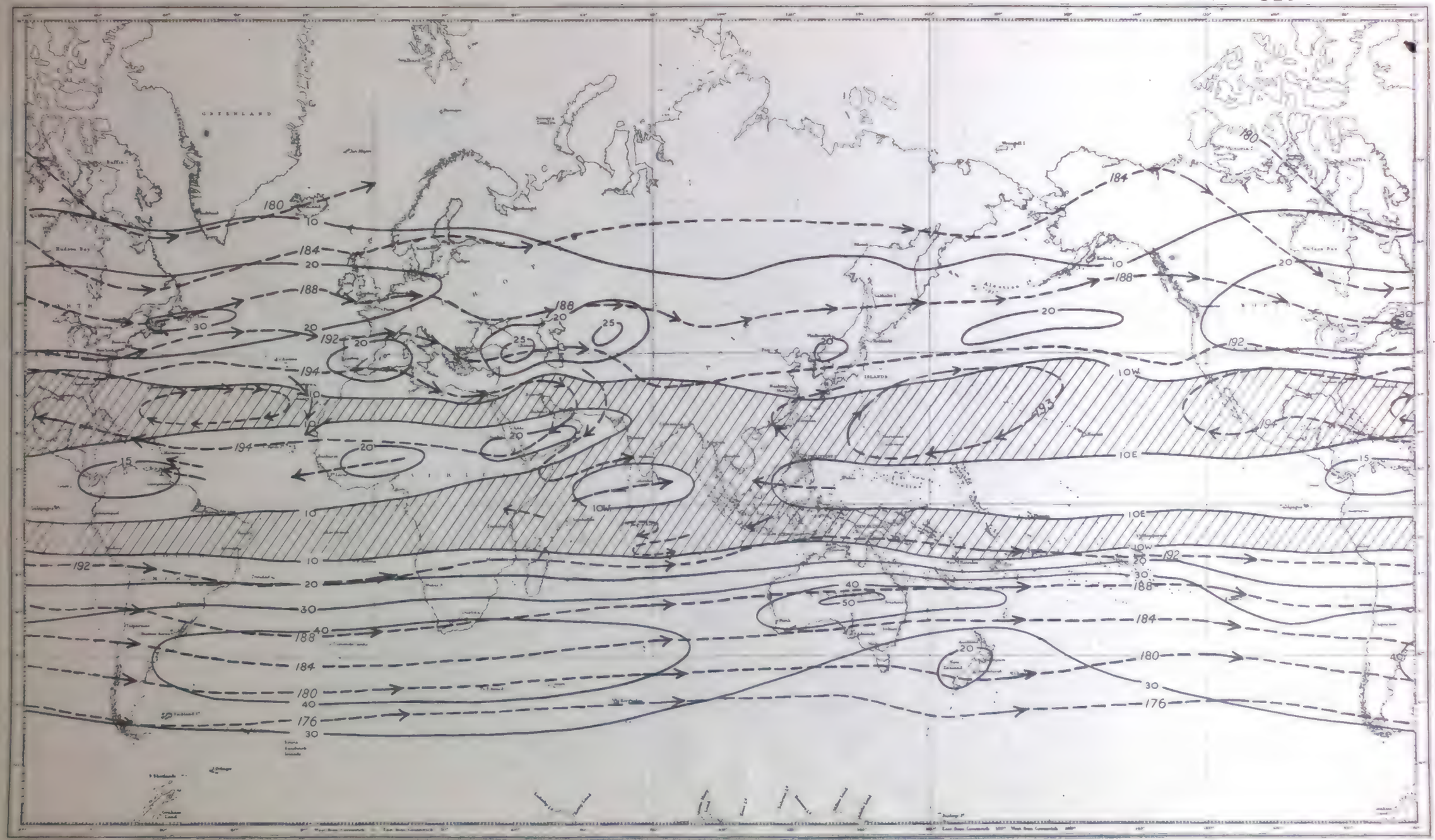

FIG. 9

JULY – 300mb.

PROVISIONAL

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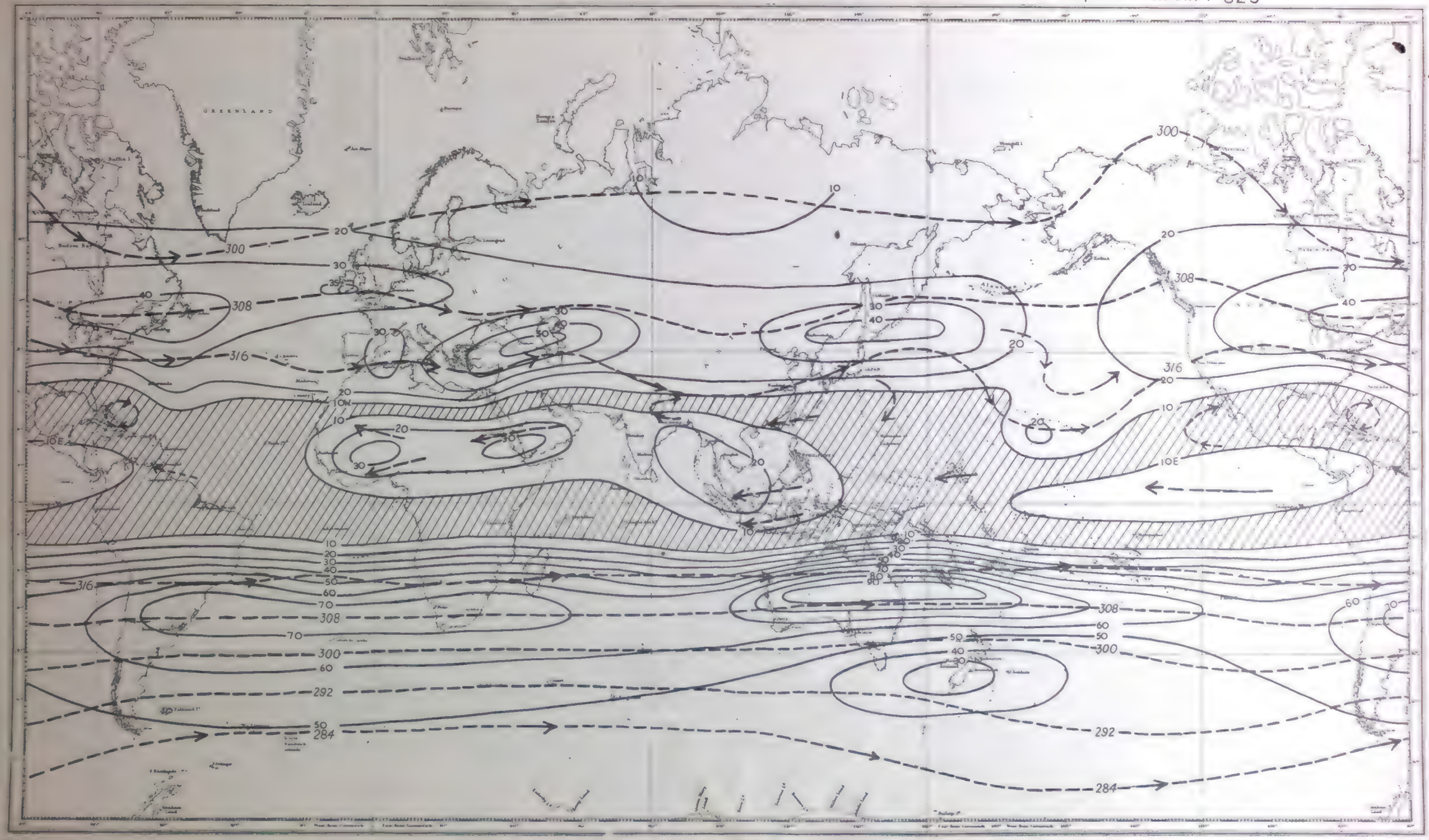

FIG. 10

JULY - 200mb

PROVISIONAL

M.R.P. 823

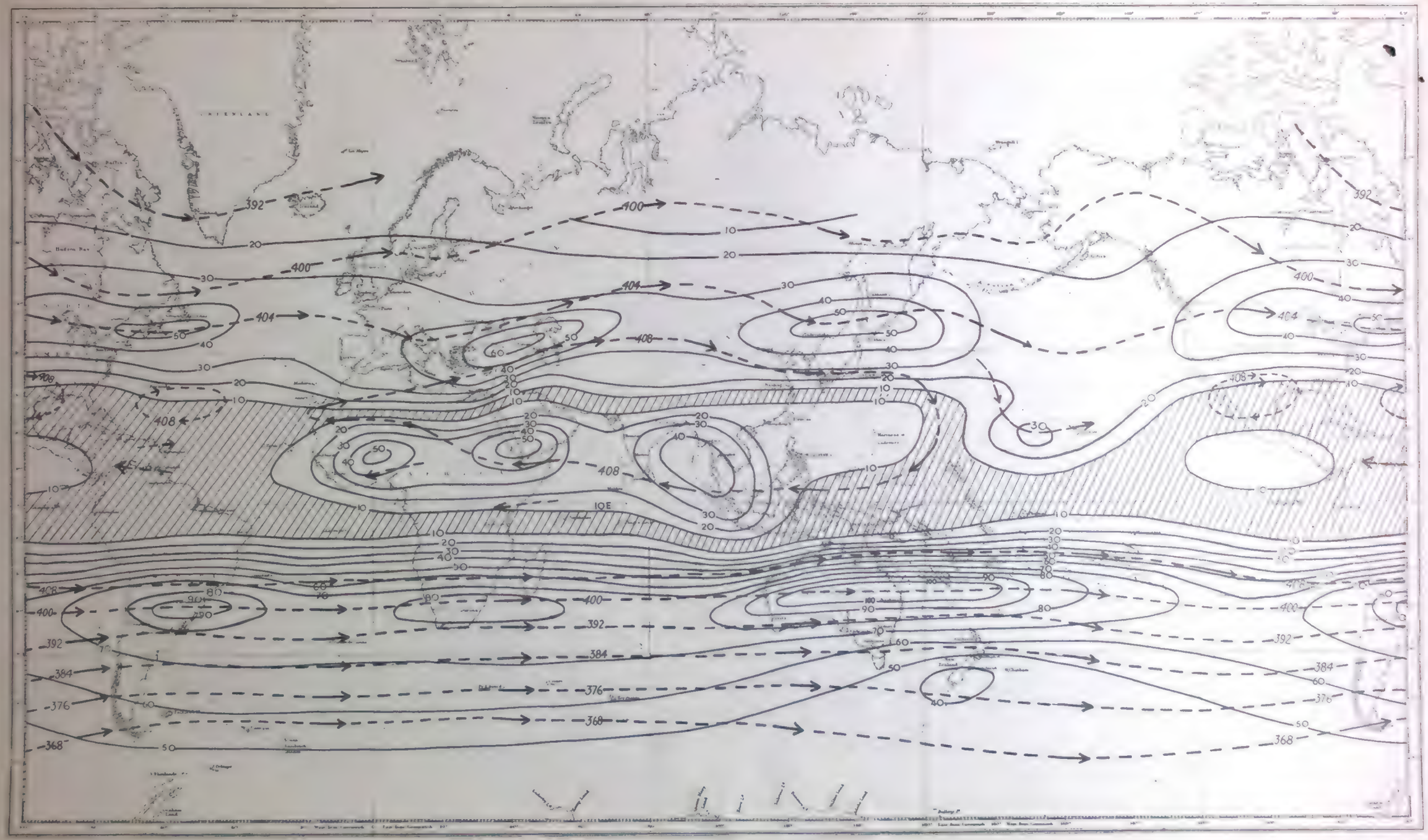

FIG. 11

JULY – 100 mb.

PROVISIONAL

M.R.P. 823

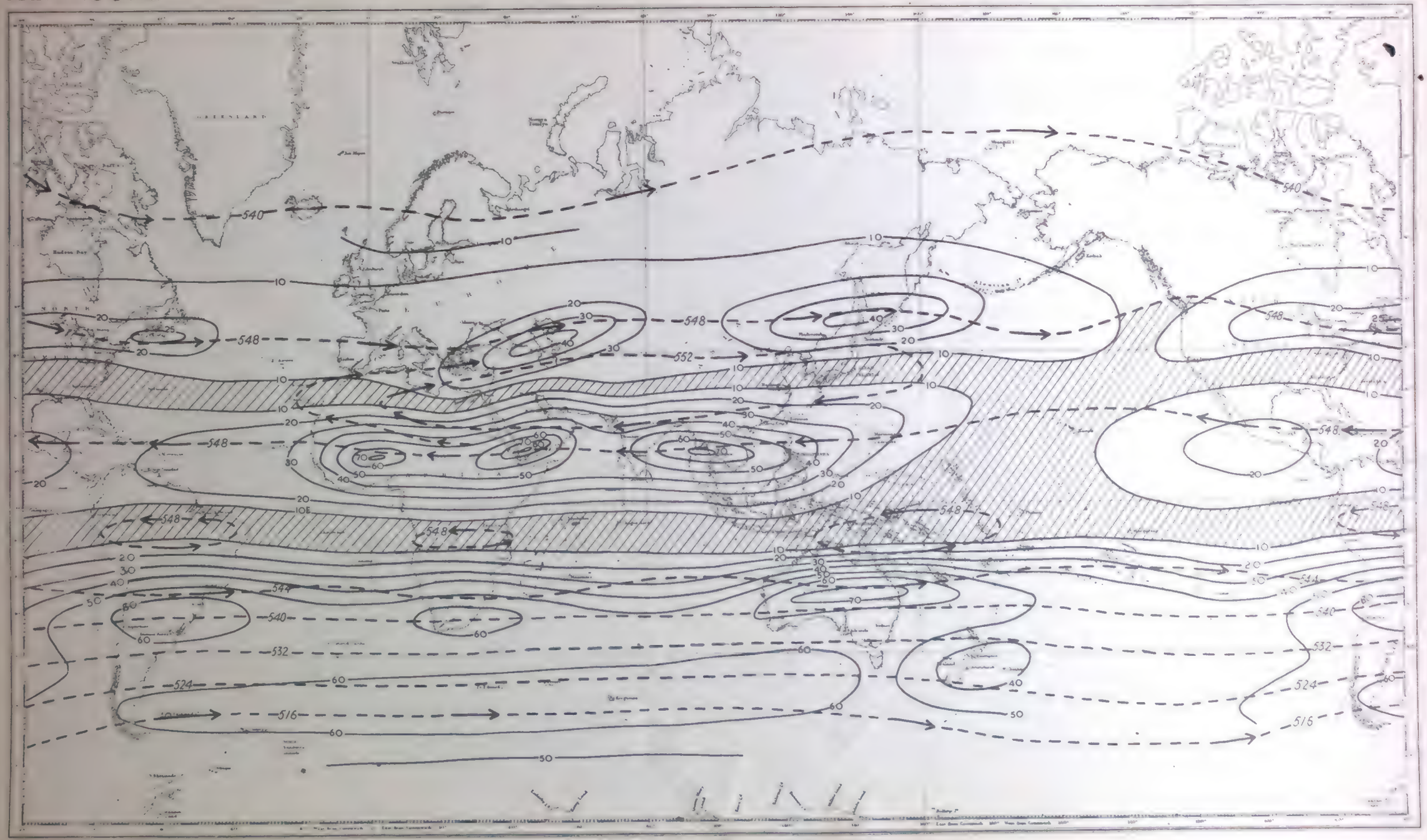

FIG. 12

OCTOBER – 500mb.

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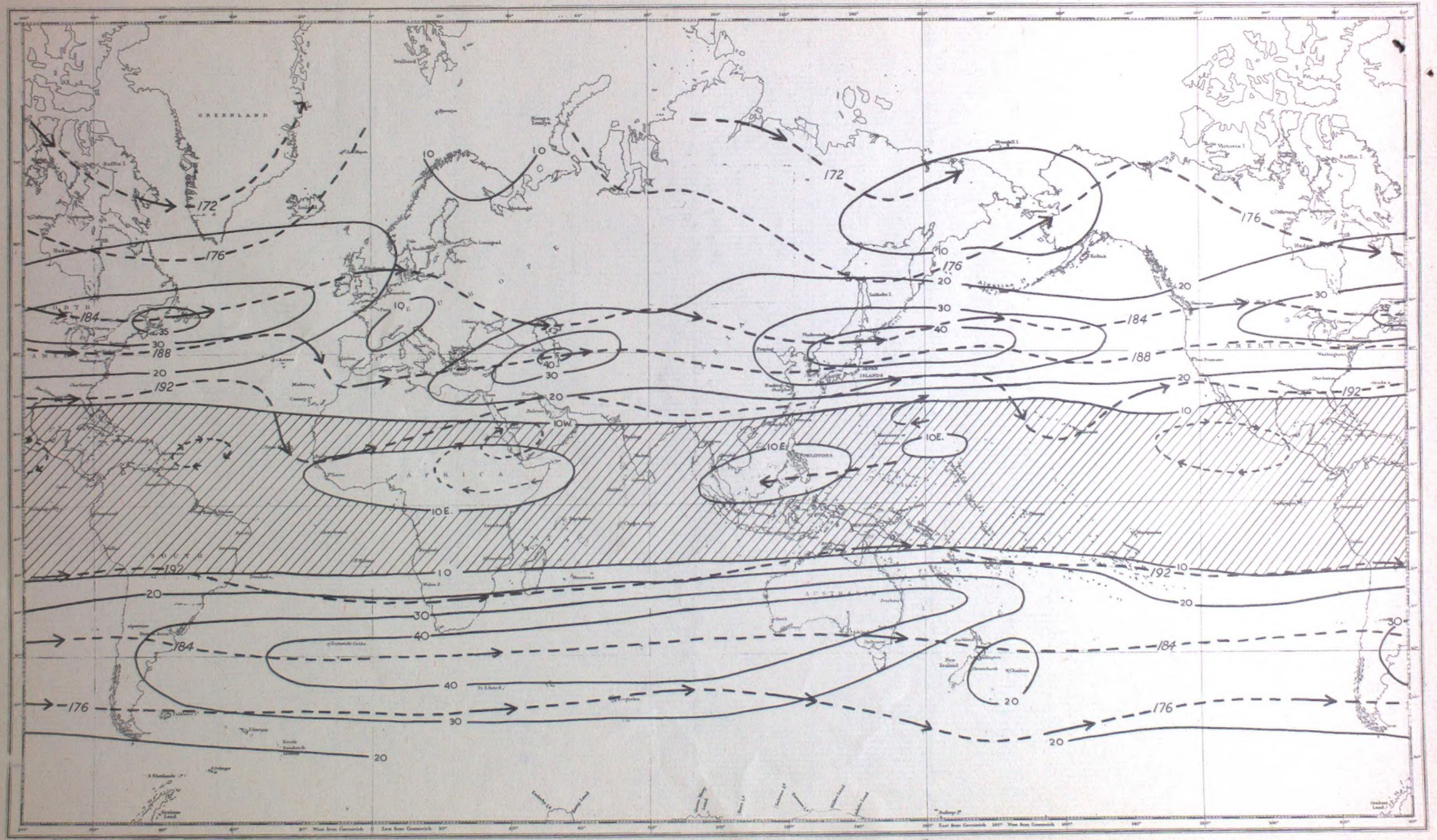

FIG. 13

OCTOBER – 300mb.

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M.R.P. 823

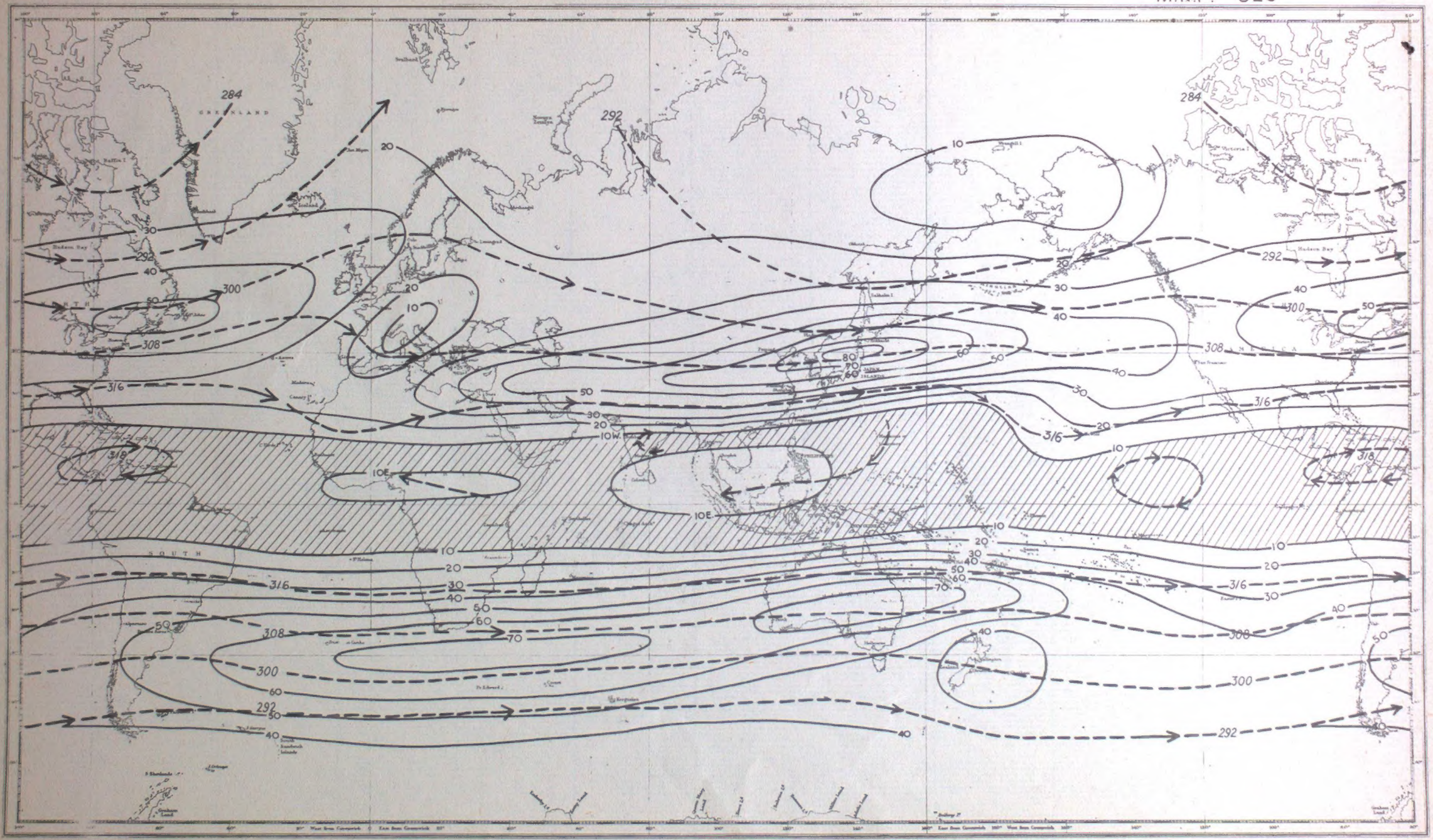

FIG. 14

OCTOBER – 200 mb.

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M.R.P. 823

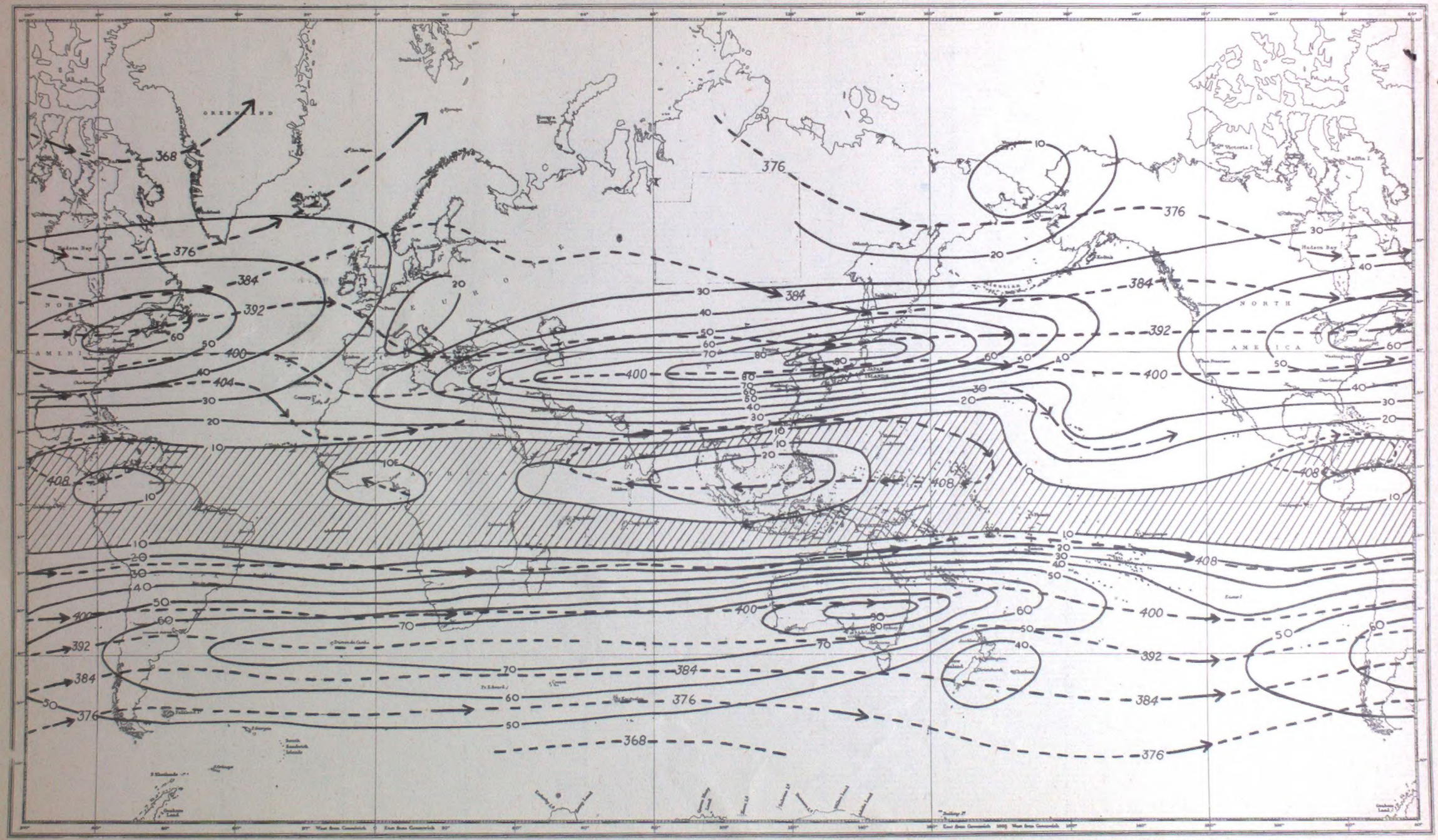

FIG. 15

OCTOBER – 100 mb.

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M.R.P. 823

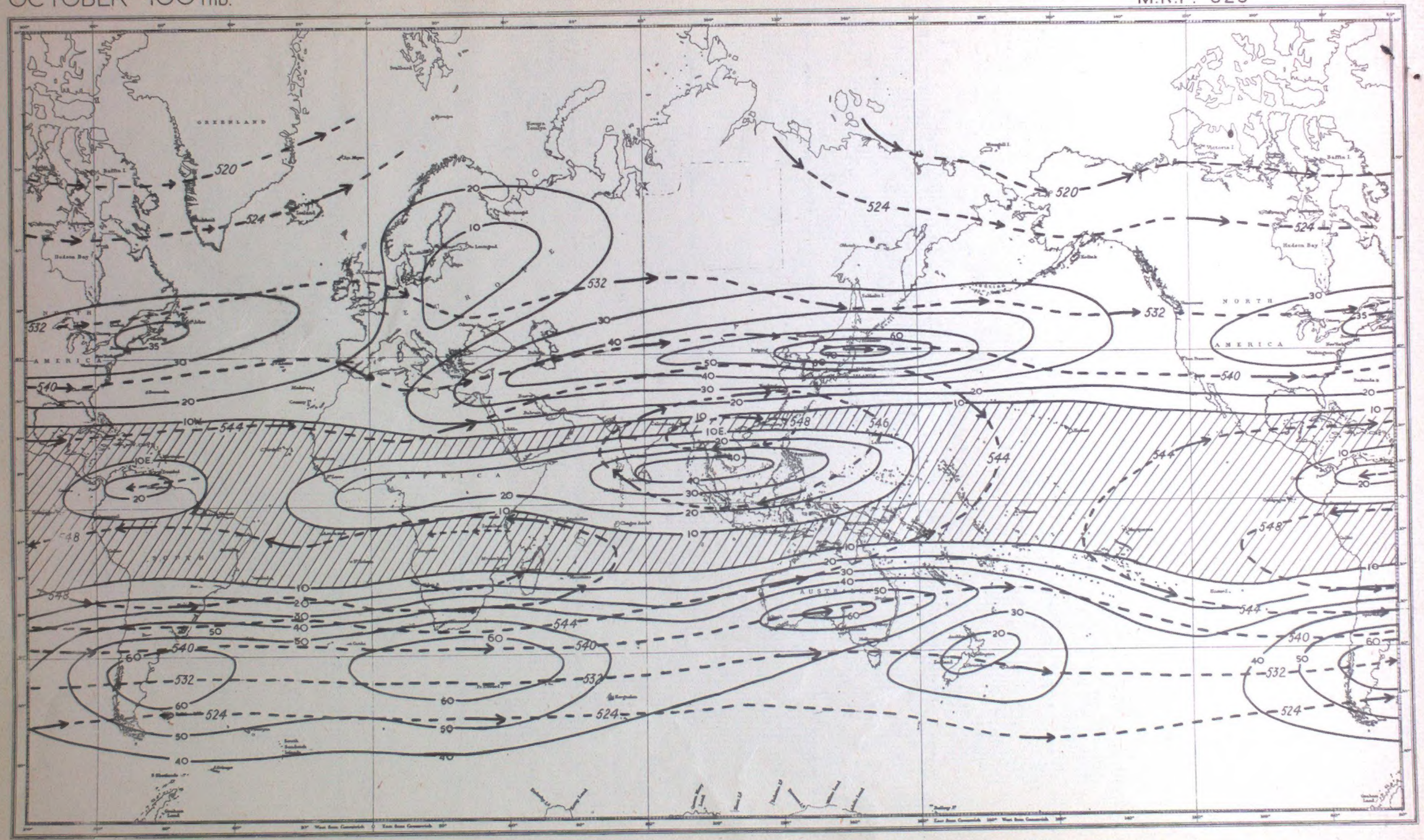

FIG. 16